CLAIMS

I claim:

1. A method for displaying an image, comprising:
   directing light onto a micromirror array;
   modulating micromirrors within the micromirror array; and
   using analog modulation in combination with digital modulation to achieve grayscale levels in the displayed image.

2. The method as in Claim 1 wherein the number of grayscale levels in the displayed image is greater than the number of time slots per image frame time.

3. An apparatus for displaying an image, comprising:
   micromirrors in a micromirror array; and
   an electronic controller which sends analog or digital control signals, depending on the light level desired, to the micromirrors in the micromirror array.

4. The apparatus as in Claim 3 wherein, the electronic controller uses an algorithm or a lookup table to convert linear encoded light level data to nonlinear analog or digital micromirror control signals.

5. The apparatus as in Claim 3 wherein, the analog control signals are amplitude modulated signals and the digital control signals are digital pulsewidth modulated signals.

6. The apparatus as in any of Claims 3, wherein each micromirror in the micromirror array has only one landing pad or mechanical stop.

7. The apparatus as in Claim 6, wherein, the micromirrors in the micromirror array are deflected by the application of electrostatic force.

8. The apparatus as in Claim 7 wherein, the micromirrors in the micromirror array are deflected to positions intermediate between the resting position and the maximum deflection position.

9. The apparatus as in Claim 8 wherein, the micromirrors in the micromirror array always return to the same position when electrostatic forces are removed.

10. The apparatus as in Claim 8 wherein, only one electrical pulse is used per image frame.

11. The apparatus as in Claim 8 wherein, more than one electrical pulse is used to direct the micromirror to a position intermediate between the resting position and the maximum deflection position.

12. The apparatus as in Claim 8 wherein, the amount of light appearing at a pixel in the image during an image frame depends on the duration of the application of electrical force to the micromirror corresponding to the pixel such that

    when the duration of the force is less than that required to move the micromirror to its position of maximum deflection, the amount of light appearing at the pixel in the image during the image frame is approximately proportional to the square of the duration of the force; and

    when the duration of the force is more than that required to move the micromirror to its position of maximum deflection, the amount of light appearing at the pixel in the image during the image frame is approximately linearly proportional to the duration of the force.

13. The apparatus as in Claim 9 wherein, when an electrical control pulse is applied to a micromirror in the micromirror array, the release of stored mechanical energy is not significant compared to the electrostatic force applied.

14. The apparatus as in Claim 13 wherein, no stored mechanical energy is released when the micromirror is deflected by electrostatic force.

15. A method for displaying an image, comprising:
directing light onto an array of tilting micromirrors;
tilting micromirrors within the micromirror array; and
using analog and digital techniques wherein the
analog techniques include tilting the micromirrors to arbitrary angles between their minimum and maximum deflection angles, and the
digital techniques include tilting the micromirrors to only their minimum or maximum deflection angles for varying time periods.

16. A method for displaying an image, comprising:
directing light onto an array of tilting, flat-plate micromirrors;
deflecting micromirrors within the micromirror array to various tilt angles;
combining analog and digital techniques to control the tilt angles according to digitally encoded pixel intensity data.

17. The method as in Claim 16 wherein,
maximum and minimum tilt angles are controlled using digital techniques for all but the least significant bit of the intensity data, and
intermediate tilt angles are controlled by analog techniques for the least significant bit of the intensity data.

18. A method for displaying an image, comprising:
directing light onto a micromirror array;
modulating micromirrors within the micromirror array; and
using partial micromirror deflection in combination with full micromirror deflection to achieve grayscale levels in the displayed image.

19. The method as in Claim 18 wherein the number of grayscale levels in the displayed image is greater than the number of time slots per image frame time.

20. An apparatus for displaying an image, comprising:
    micromirrors in a micromirror array; and
    an electronic controller which sends control signals appropriate to partially deflect or fully deflect, depending on the light level desired, the micromirrors in the micromirror array.

21. The apparatus as in Claim 20 wherein, the electronic controller uses an algorithm or a lookup table to convert linear encoded light level data to micromirror control data that results in partial or full micromirror deflection signals.

22. The apparatus as in Claim 20 wherein, the analog control signals are amplitude modulated signals and the digital control signals are digital pulsewidth modulated signals.

23. The apparatus as in any of Claim 20 wherein, each micromirror in the micromirror array has only one landing pad or mechanical stop.

24. The apparatus as in Claim 23 wherein, the micromirrors in the micromirror array are deflected by the application of electrostatic force.

25. The apparatus as in Claim 24 wherein, the micromirrors in the micromirror array are deflected to positions intermediate between the resting position and the maximum deflection position.

26. The apparatus as in Claim 25 wherein, the micromirrors in the micromirror array always return to the same position when electrostatic forces are removed.

27. The apparatus as in Claim 25 wherein, only one electrical pulse is used per image frame.

28. The apparatus as in Claim 25 wherein, more than one electrical pulse is used to direct the micromirror to a position intermediate between the resting position and the maximum deflection position.

29. The apparatus as in Claim 25 wherein, the amount of light appearing at a pixel in the image during an image frame depends on the duration of the application of electrical force to the micromirror corresponding to the pixel such that

when the duration of the force is less than that required to move the micromirror to its position of maximum deflection, the amount of light appearing at the pixel in the image during the image frame is not linearly proportional to the duration of the force; and

when the duration of the force is more than that required to move the micromirror to its position of maximum deflection, the amount of light appearing at the pixel in the image during the image frame is approximately linearly proportional to the duration of the force.

30. The apparatus as in Claim 26 wherein, when an electrical control pulse is applied to a micromirror in the micromirror array, the release of stored mechanical energy is not significant compared to the electrostatic force applied.

31. The apparatus as in Claim 30 wherein, no stored mechanical energy is released when the micromirror is deflected by electrostatic force.

32. A method for displaying an image, comprising:

directing light onto a micromirror array;

modulating micromirrors within the micromirror array; and

using partial micromirror deflection to achieve grayscale levels in the displayed image.

33. The method as in Claim 32 wherein the partial micromirror deflection is a deflection of one or more micromirrors to an angle or angles that are less than the maximum possible deflection angle for each micromirror in the micromirror array.

34. The method as in Claim 33 wherein the maximum deflection angle is greater than 14 degrees.

35. A method for displaying an image, comprising:
directing light onto a micromirror array;
deflecting micromirrors within the micromirror array; and
using a plurality of deflection angles to achieve grayscale levels in the displayed image.

36. A method for displaying an image, comprising:
directing light onto a micromirror array;
deflecting micromirrors within the micromirror array to any of a plurality of deflection angles; and
deflecting the micromirrors to the deflection angles for varying amounts of time.

37. The method as in Claim 36 wherein the deflection angles are within the range from –20 to +20 degrees deflection measured from the rest position.

38. The method as in Claim 36 wherein the plurality of deflection angles includes at least three different angles.

39. A method for displaying an image, comprising:
directing light onto a micromirror array;
deflecting micromirrors within the micromirror array; and
using a plurality of deflection angles to achieve grayscale levels in the displayed image wherein,

the maximum deflection angle is used for varying amounts of time when medium or bright light levels in the displayed image are desired and

intermediate deflection angles are used when dim light levels in the displayed image are desired.

40. The method as in Claim 39 wherein, the maximum deflection angle is in the range 12 to 20 degrees from the rest position and the intermediate deflection angles are in the range 0.5 to 11.5 degrees from the rest position.

41. The method as in Claim 39 wherein, the maximum deflection angle is in the range +12 to +20 degrees or –12 to –20 degrees from the rest position and the intermediate deflection angles are in the range +0.5 to +11.5 degrees or –0.5 to –11.5 degrees from the rest position.

42. A method for displaying an image, comprising:

directing light onto a micromirror array;

deflecting micromirrors within the micromirror array to any one of a plurality of angles less than 12 degrees from their rest position when low light levels are desired in the image; and

deflecting micromirrors within the micromirror array to a single maximum angle greater than 12 degrees from their rest position for variable amounts of time when brighter light levels are desired in the image.

43. A method for displaying an image, comprising:

directing light onto a micromirror array;

deflecting micromirrors within the micromirror array to any one of a plurality of angles less than x degrees from their rest position when low light levels are desired in the image; and

deflecting micromirrors within the micromirror array to a single maximum angle greater than x degrees from their rest position for variable amounts of time when brighter light levels are desired in the image.

44. The method as in Claim 43 wherein the single maximum angle is defined by the position where the movement of the micromirrors is stopped by a mechanical stop.

45. A method for displaying an image, comprising:
directing light onto a micromirror array;
deflecting micromirrors within the micromirror array to any one of a plurality of angles including a non-deflected position wherein,
one of the angles corresponds to maximum brightness of the image, another angle corresponds to intermediate brightness of the image, and the third angle corresponds to minimum brightness of the image.

46. The method as in Claim 45 wherein, the non-deflected position of the micromirror lies between the angles corresponding to maximum and minimum brightness.

47. The method as in Claim 45 wherein, either of the two extreme angles corresponds to the non-deflected position of the micromirror.

48. A method for displaying an image, comprising:
directing light onto a micromirror array;
deflecting micromirrors within the micromirror array to a negative angle when low light levels are desired in the image;
allowing micromirrors to remain in their rest position when intermediate light levels are desired in the image; and
deflecting micromirrors within the micromirror array to a positive angle when bright light levels are desired in the image.

49. The method as in Claim 48 wherein the negative and positive angles are defined by the positions where the movement of the micromirrors is stopped by a mechanical stop or stops.

50. The method as in Claim 48 wherein no observable light is displayed at pixels corresponding to micromirrors deflected to the negative angle.

51. The method as in Claim 48 wherein micromirrors deflected to the positive angle remain there for varying amounts of time depending on the pixel brightness desired.

52. A method for displaying an image, comprising:
directing light onto a micromirror array;
deflecting micromirrors within the micromirror array; and
using a plurality of deflection angles to achieve grayscale levels in the displayed image wherein one or more angles of the possible deflection angles for each micromirror are defined by positions where the micromirror touches one or more mechanical stops.

53. The method as in Claim 52 wherein each micromirror is capable of rotating about a first axis until the micromirror hits a first stop and then further rotating about a second axis until the micromirror hits a second stop.

54. The method as in Claim 53 wherein the first axis and the second axis are parallel.

55. A method for displaying an image, comprising:
directing light onto a micromirror array;
modulating micromirrors within the micromirror array; and,
using analog modulation in combination with digital modulation to achieve grayscale levels in the displayed image, wherein
analog modulation includes operation of a micromirror where the micromirror is deflected to an angle θ_1 less than its maximum possible deflection angle θ_{max} and remains deflected to angle θ_1 with approximately zero angular velocity for longer than an instantaneous time, i.e. the time for which the angular velocity is zero during a velocity reversal encountered at the extreme points in the motion of a vibrating micromirror in the absence of electrostatic driving forces.

56. The method as in Claim 55 wherein the digital modulation is pulsewidth modulation.

57. The method as in Claim 55 wherein the micromirror is deflected to, or stopped at, angle θ_1 through the application of analog control voltages to one or more control electrodes.

58. The method as in Claim 55 wherein the micromirror is deflected to, or stopped at, angle θ_1 by mechanical stops.

59. The method as in Claim 55 wherein the micromirror is deflected to, or stopped at, angle θ_1 by remaining at a natural rest position intermediate between positions achieved by electrostatic actuation.

60. The method as in Claim 55 wherein the micromirror is deflected to one of a plurality of possible deflection angles θ_i less than its maximum possible deflection angle θ_{max}.

61. A method for displaying an image, comprising:
directing light onto a micromirror array;
deflecting micromirrors within the micromirror array to any one of a plurality of angles less than 12 degrees from their rest position when low light levels are desired in the image; and
deflecting micromirrors within the micromirror array to a single maximum angle greater than 12 degrees from their rest position under pulsewidth modulation when brighter light levels are desired in the image.

62. A method for displaying an image, comprising:
directing light onto a micromirror array;
deflecting micromirrors within the micromirror array; and
using a plurality of micromirror deflection angles to achieve grayscale levels in the displayed image wherein the brightness of one or more pixels in the image is

controlled by analog modulation of a micromirror or micromirrors and the brightness of one or more other pixels in the image is controlled by digital pulsewidth modulation of a micromirror or micromirrors.

63. A spatial light modulator, comprising:
an array of micromirrors on a substrate; and
an electronic controller programmed with a lookup table, wherein
the controller converts 8-bit video data into 10-bit or 12-bit micromirror control signals;
the micromirrors are partially deflected in response to control signals for low brightness pixels; and,
the micromirrors are fully deflected under pulsewidth modulation in response to control signals for high brightness pixels.